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(71) Applicant: **AIR-MAZE CORPORATION** [US/US]; 115 East Steels Corners Road, P.O. Box 1459, Stow, OH 44224-0459 (US).

(72) Inventor: **KELLER, Dennis, B.**; 1392 East Pershing, Salem, OH 44460 (US).

(74) Agents: **HILL, Stephen, A.** et al.; Rankin, Hill, Porter & Clark LLP, 700 Huntington Building, 925 Euclid Avenue, Cleveland, OH 44115-1405 (US).

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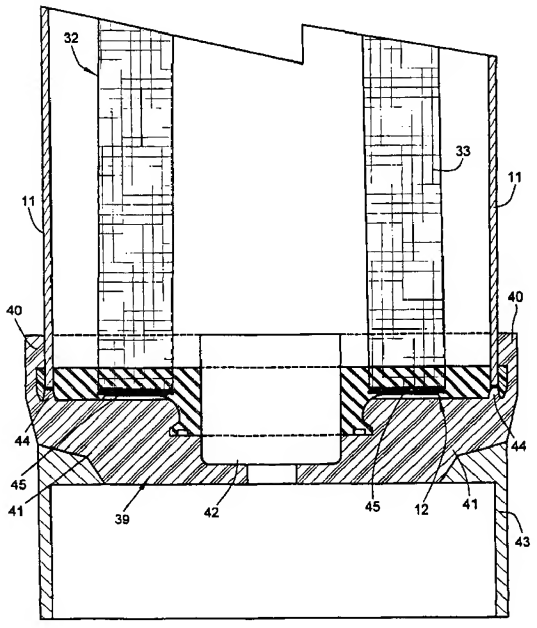
(54) Title: METHOD OF MAKING A FILTER ASSEMBLY USING A MOLD MADE FROM A MODULAR MASTER




(57) Abstract: A method of making a filter assembly includes the steps of providing a side housing member and a filter element, providing an end cap master, making an end cap mold from the end cap master, and molding at least one end cap using the end cap mold with the filter element within the housing body member and a portion of the housing body member attached to the end cap.

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# METHOD OF MAKING A FILTER ASSEMBLY USING A MOLD MADE FROM A MODULAR MASTER

## BACKGROUND OF THE INVENTION

### 1. Field of the Invention

This invention relates to the fabrication of filters, filter/coalescers, filter components, and filter assemblies, and more particularly to filters having end caps which are molded in place on each end of a cylindrical housing member.

### 2. Description of the Prior Art

The configuration of many types of filters for use in gas or liquid streams includes a generally cylindrical housing with end caps on each end. The end caps are made of a thermosetting plastic material, and are typically molded in place. The mold-in-place process typically provides that of the filter assembly which are sealed to the end caps have ends or edges which are embedded in the end caps as the end caps are molded. For example, the ends of the cylindrical housing and the filter element are typically molded into the end cap to seal them to the end cap in a cost effective manner. Because these elements are molded or "potted" in place, the molding of the end caps must take place in an open mold in which the plastic resin material is poured and allowed to cure or set.

The configuration of these molded end caps is restricted by the molding process in which the end caps are made. The configuration cannot include any "undercuts" which would make the end cap impossible to remove from the unitary mold. "Undercuts" are portions of the molded piece which are set back from other portions above them. These set-back portions could not be removed from the mold because mold portions forming the larger portions above would block their release. The conventional method for dealing with

undercuts is to provide a segmented mold, in which the mold can be taken apart to release the molded member. However, in the molding of filter end caps, the use of segmented molds significantly adds to the manufacturing costs, since the molds must be disassembled and reassembled with the molding of each end cap. Furthermore, segmented molds are more expensive to make and more difficult to maintain in alignment. If the mold is misaligned, flashing is created which detracts from the appearance and function of the end cap.

Filters are typically available in a variety of sizes and configurations. The end caps on these filters must, therefore, be made in a variety of sizes and configurations. Each different size and configuration of an end cap has required a different size and configuration mold. The cost of making and maintaining all of these different sized and configured molds adds to the cost of making a full line of filters.

## SUMMARY OF THE INVENTION

The present invention provides a unique method for making filters, such as air filters, which overcomes the problems and shortcomings of the prior art. In accordance with the present invention, it is possible to mold end caps in a single unitary unsegmented mold and provide undercuts in the configuration of the end caps, without creating excessive difficulty in removing the molded end cap from the mold. The present invention also provides an easy and relatively inexpensive method for making a wide variety of end cap molds having different sizes and configurations while significantly reducing the cost of tooling for each individual molds.

The method of the present invention utilizes molds for making the end caps made of a flexible silicone rubber material. The flexibility of the silicone rubber material permits undercuts to be designed into the end cap configuration. If there is an undercut, the flexibility of the mold material permits the portion of the mold above the undercut to move out of the way when the end cap is removed from the mold without damage to the mold or to the molded end cap.

The silicone rubber mold is made from a master assembly comprising a plurality of interchangeable components. Different sized and shaped components are available corresponding to different sizes and shapes for the end caps. Using the modular master assembly, it is possible to provide an array of molds for providing end caps of various sizes and configurations without the expense of tooling individual molds for each configuration. The only tooling costs are those associated with making each of the master components, and the assembly of these components can be used to make a large number of different molds.

These and other advantages are provided by the present invention of a method of making a filter assembly comprising the steps of providing a side housing member and a filter element, providing a end cap master, making an end cap mold from the end cap master, and molding at least one end cap using the end cap mold with the filter element within the housing body member and a portion of the housing body member attached to the end cap.

Preferably, the mold is made of a flexible material, and more particularly of silicone rubber. Further preferably, the master is made of a plurality of interchangeable components which can be selectively assembled to provide a mold for making an end cap of a desired size and configuration.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a side sectional view of a filter assembly made according to the present invention.

FIG. **2** is a side sectional view of one of the end caps of the filter assembly of FIG. **1** being molded using a mold made according to the present invention.

FIG. **3** is a side sectional view of a master assembly used to make the mold of FIG. **2**.

FIG. **4** is a side sectional view similar to FIG. **1** showing a different filter assembly made according to the present invention.

FIG. **5** is a side sectional view of one of the end caps of the filter assembly of FIG. **4** being molded using a mold made according to the present invention.

FIG. **6** is a side sectional view of the other end cap of the filter assembly of FIG. **4** being molded.

FIG. **7** is a side sectional view of a master assembly used to make the molds of FIGS. **5** and **6**.

FIG. **8** is a side sectional view of another master assembly used to make the filter retainer.

FIG. **9** is a side sectional view similar to FIG. **1** of another different filter assembly made according to the present invention.

FIG. **10** is a side sectional view of one of the end caps of the filter assembly of FIG. **9** being molded using a mold made according to the present invention.

FIG. **11** is a side sectional view of a master assembly used to make the mold of FIG. **10**.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring more particularly to the drawings and initially to FIG. **1**, there is shown a filter assembly **10**, which is typical of the filter assemblies which utilize the present invention. The filter assembly **10** may be any type of air filter or other similar fluid filter assembly. The filter assembly **10** shown in FIG. **1** is typical of those used as vacuum filters, and generally comprises a housing comprising a cylindrical side housing member **11** and a pair of end caps **12** and **13**, forming a filter chamber **14** therein. The ends of the side housing member **11** are embedded into the end caps **12** and **13**. The first end cap **12** includes a neck **15** extending axially from the center of the end cap **12**. A gas outlet **16** is formed by a passage extending inside the neck **15** for the carrying filtered air from the filter assembly. The neck **15** is intended for attachment to an adapter **17** which is preferably made of metal, such as aluminum, and provides a hex surfaced exterior and a threaded interior so that the inlet can be connected to suitable conduit **18** which carries the filtered air from the filter assembly. An outer flange **19** is formed around the end of the neck which is attached to the adapter **17** using a V-clamp **20**, with a gasket seal **21** provided in a corresponding recess at

the end of the neck **15** to seal the end cap **12** to the adapter **17**. The other end cap **13** has a similar configuration with a neck **22** forming a gas inlet **23** for the introduction of dirt laden air into the filter assembly, and a flange **24** around the neck **22** for attachment to another adapter **25** by which the end cap is connected to suitable conduit **26** which carries the dirt laden air.

Within the filter chamber **14** is a filter element **32** which provides the filtering function for the air which travels through the filter assembly **10**. The filter element **32** has a desirable axially symmetrical shape. Preferably, the filter element **32** is conical or frustoconical in shape, as shown in FIG. **1**, but the filter element may also be made in a conventional cylindrical shape if desired, or any other desirable axially symmetrical shape. The filter element **32** includes a media pack **33** which may be comprised of any suitable combination of filtering materials, such as fiberglass, polyester, polypropylene or metal, some of which may be pleated in a conventional manner, or which may be molded, wrapped or otherwise shaped. The media pack **33** may also includes an outer wrap layer on the exterior of the filter media pack. A support member **34**, in the form of a cylindrical or frustoconical tube of expanded metal, is provided along the interior surface of the filter media pack **33**. The media pack **33** is held together at one end by a conical retainer cap **35** which is molded in place using a semi-rigid hardenable material, such as foamed urethane, with the end of the media pack embedded in the end cap **35**. The other end of the media pack **33** is embedded in the filter assembly end cap **12.**

The filter assembly **10** thus operates with dirt laden air from the conduit **26** passing through the gas inlet **23** and into the filter chamber **14**. The air flow is diverted by the end cap **35** of the filter element **32** and passes through the media pack **33** in a generally radial direction into the interior of the filter element **32**. From there, the filtered air flows through the gas outlet **16** into the conduit **18.**

The filter assembly end caps **12** and **13** are each molded from a semi-rigid hardenable material using a unique flexible mold **39**, which is shown in FIG. **2**. The end cap mold **39** is, in turn, itself molded from a flexible silicone rubber material, as will be explained in detail below. Both end caps **12** and **13** are made in a similar manner, and the fabrication of both will be described with respect to the end cap **12**. As shown in FIG. **2**, the end cap mold

39 has side portions 40 which fit around and support the cylindrical side housing member 11, and has a bottom portion 41 which forms the outer end profile of the end cap 12. A mold plug 42 is used to form the gas inlet 23. To form the end cap 12, the mold 39 is set up horizontally with a suitable mold support 43 as shown in FIG. 2, and the plug 42 is centered in the mold 39. The cylindrical housing member 11 is placed in the mold 39, with the outer side rim 40 supporting and positioning the housing member 11. The end of the housing member 11 preferably rests on a plurality of support tabs 44 which extend above the top inner surface of the mold, so that the housing member does not extend entirely through the end cap. Typically, four support tabs 44 are provided, circumferentially spaced 90° apart around the top inner surface of the mold. The filter element 32 is placed in the mold 39 with the media pack 33 resting on the upper surface of the bottom portion 41 and centered in place. If desired, a media spacer 45, such as that described in US-5 891 337-A may be placed in the mold 39 before the media pack 33 is placed to prevent the end of the media pack from being exposed to the exterior surface of the end cap 12. The mold 39 is then filled to a predetermined level with the semi-rigid hardenable material which is used to form the end cap, such as foamed urethane. The urethane is allowed to set, after which the end cap 12 is removed from the mold 39. The depressions 46 (FIG. 1) formed by the support tabs 44 may be filled with an appropriate sealing material such as silicone or caulk. The other end cap 13 is made in essentially the same way, except that filter element 32 is not placed into the mold 39.

It will be noted that the flange 19 around the outlet on the end cap 12 extends radially outwardly from the neck 15 of the end cap and that the remainder of neck is thus radially recessed from the flange. This presents an undercut in the mold configuration. Using an ordinary inflexible mold material, it would not be possible to remove the end cap 13 from the mold 39, unless the mold was segmented. However, since the mold 39 is made of a flexible silicone rubber material, it is possible to release the end cap 13 from the mold 39 after it has set with only a nominal amount of force and without damage to the mold 39. The flexibility of the silicone rubber material allows portions of the mold 39 move away from a position which would otherwise lock the molded end cap in the mold.

The flexibility of the mold **39**, and its use of a silicone rubber material, may limit the expected life of the mold to less than would be possible using an inflexible, rigid mold material. However, new molds can be quickly and easily made using the unique modular master assembly **50** which will now be described in more detail with reference to FIG. **3**. The end cap master assembly **50** shown in FIG. **3** comprises a base **51**, an annular outer body **52** which rests on the base **51** and forms the sides of the end cap mold **39**, and a top plate **53** which rests on the outer body. A center blank **54** also rests on a center recess in the base **51**. A peripheral outer ring **56** fits around the outside of the center blank **54**. The outer ring includes a plurality of indentations **57** which form the support tabs **44** in the end cap mold. The center blank **54** and the outer ring **56** together approximate the shape of the end cap **13**.

To make an end cap mold **39**, the master assembly **50** is assembled as shown in FIG. **3**, and the mold assembly is filled with a room temperature vulcanizing (RTV) silicone rubber material. Suitable RTV silicone rubber materials include RTV662A and RTV662B, available from GE Silicones of Waterford, New York, U.S.A. Prior to introducing the silicone rubber material, the master assembly **50** may be coated with a sealer or release compound to enhance the release of the silicone rubber from the master and to minimize cure inhibition. The silicone rubber material, which typically is supplied as a base material and a curing agent, is mixed according to manufacturer's instructions. The mixture is introduced into a form containing the master assembly **50**. The silicone rubber is then allowed to cure, which may take several hours, after which the silicone rubber mold **39** is removed from the foam and is ready for use.

It is noted that the master assembly **50** is formed of a plurality of modular components, any of which may be replaced by a comparable component having a different shape or different dimensions, so that the components of the master assembly can be changed to make molds for different sized and different shaped end caps. For example, the outer ring **56** can be replaced with a compatible ring having a smaller diameter to produce a smaller diameter end cap. Alternatively, the center blank **54** can be replaced with a different center blank to achieve a different outlet configuration for the end cap.

An example of the interchangeability of the master components can be seen with reference to FIGS. **4-7**. FIG. **4** shows another filter assembly **10***a* which comprises a

housing formed of a cylindrical side housing member **11** and a pair of end caps **12***a* and **13***a*, forming a filter chamber **14***a* therein. The ends of the side housing member **11** are embedded into the end caps **12***a* and **13***a*. The first end cap **12***a* includes a neck **15***a* extending axially from the center of the end cap **12***a*. A gas outlet **16***a* is formed inside the neck **15***a* for carrying filtered air away from the filter assembly. The gas outlet passage inside the neck **15***a* contains interior threads for threaded attachment of the filter assembly to a suitable conduit (not shown). The other end cap **13***a* has a similar configuration with a neck **22***a* having a central passage therethrough forming a gas inlet **23***a* for introducing dir laden air into the filter assembly, with the gas inlet passage also being threaded for connection to a suitable conduit (not shown). Within the filter chamber **14***a* is the filter element **32** which includes the media pack **33** and the support member **34**, with the media pack **33** held together at one end by the conical retainer cap **35**. The other end of the media pack **33** is embedded in the filter assembly end cap **13***a*.

The filter assembly end caps **12***a* and **13***a* are each molded from the semi-rigid hardenable material similarly to the end caps **12** and **13**, but using the flexible mold **39***a*, which is shown in FIGS. **5** and **6**. As shown in FIG. **5**, the end cap mold **39***a* has side portions **40***a* which fit around and support the cylindrical side housing member **11**, and has a bottom portion **41***a* which forms the outer end profile of the end caps **12***a* and **13***a*. A mold plug **42***a* is used to form the gas outlet **16** and the gas inlet **23**. Unlike the mold plug **42**, the mold plug **42***a* has external threads which form the internal threads inside the gas outlet and inlet passages. To form the end cap **12***a*, the mold **39***a* is set up horizontally with the mold support **43** as shown in FIG. **5**, and the plug **42***a* is centered in the mold **39***a*. The cylindrical housing member **11** is placed in the mold **39***a*, with the outer side rim **40***a* supporting and positioning the housing member **11**, The end of the housing member **11** preferably rests on a plurality of support tabs **44***a* which extend above the top inner surface of the mold, so that the housing member does not extend entirely through the end cap. The filter element **32** is placed in the mold **39***a* with the media pack **33** resting on the upper surface of the bottom portion **41** and centered in place. A media spacer **45**, such as that described in U.S. Pat. No. 5,891,337, may be placed in the mold **39***a* before the media pack **33** is placed to prevent the end of the media pack from being exposed to the exterior surface

of the end cap **12***a*. The mold **39***a* is then filled to a predetermined level with the semi-rigid hardenable material. The material is allowed to set, after which the end cap **12***a* is removed from the mold **39***a*. The depressions **46***a* formed by the support tabs **44***a* are filled with an appropriate sealing material such as silicone or caulk.

The other end cap **13***a* is then made in essentially the same way. As shown in FIG. **6**, the mold plug **42***a* is now used to form the gas inlet **23**, with the external threads on the mold plug forming the internal threads inside the gas inlet passage. The mold **39***a* is set up horizontally with the mold support **43** as shown in FIG. **6**, and the plug **42***a* is centered in the mold **39***a*. The other end of the cylindrical housing member **11** is placed in the mold **39***a*, with the outer side rim **40***a* supporting and positioning the housing member **11**, and the end of the housing member resting on the support tabs **44**. The mold **39***a* is then filled to a predetermined level with the semi-rigid hardenable material. The material is allowed to set, after which the end cap **13***a* is removed from the mold **39***a*, and the depressions **46***a* are sealed

A reinforcing ring **60** may be placed in the mold before it is filled with the hardenable material to provide reinforcement to the end cap **13**. The ring **60** is made from pleated filter media. Although not shown in FIG. **1**, a similar reinforcing ring may also be provided in the end cap **13**.

The end cap mold **39***a* is made from a master assembly **50***a* shown in FIG. **7**. The master assembly **50***a* comprises the base **51**, the outer body **52**, and the top plate **53** used with the master assembly **50**, but with a different center blank **54***a* being used with the outer ring **56**. The center blank **54***a* has a different shape than the center blank **54**, resulting in a different shape for the end cap **13***a* which is made using a mold created from the master assembly **50***a*. However, the master assembly components **51**, **52**, **53** and **56** from the master assembly **50** are all reused in the master assembly **50***a*.

Because the process of producing the end cap molds **39***a* entails pouring the silicone into the master assembly **50***a* and applying a vacuum, the top surface of the silicone remains rough and uneven. Therefore, the end cap molds **39***a* are made upside down. In other words, the end cap molds **39***a* are turned over and used 180° from the horizontal position in which they are made. By making the end cap molds **39***a* upside down, the rough and uneven

surface of the mold is down on the assembly surface. When the urethane is poured into the molds **39***a* to form the end caps **12***a* and **13***a*, it is important that the molds be level so that the end caps are made with a uniform thickness. The level orientation of the end cap molds becomes more important as the size of the filter assembly increases.

In order to assure that the end caps **12***a* and **13***a* are molded in a level mold, the master assemblies **50***a* are provided with a uniform and controlled surface on what becomes the bottom of the molds **39***a*. This controlled surface is formed by the top plate **53**, and comprises two or more annular surfaces at different angles to the axis of the mold. The resulting controlled surface formed on the bottom portion **41***a* of the mold **39***a* cooperates with corresponding surfaces on the top of the mold support **43**, as shown in FIGS. **5** and **6**. The mold support **43** thus conforms to the controlled surface on the mold **39***a*, and the molds are held in a level orientation during the molding process without further consideration or effort on the part of the molding personnel. The mold support **43** rests on a level work surface, or is shimmed so that it is perfectly level, and the molds which rest in the support are maintained in a proper level orientation.

The modular master assembly concept may also be used to make a mold which is used to form the retainer cap **35** on the filter element **32**. FIG. **8** shows another master assembly **50***b* which is used to make a mold for the filter element retainer cap **35**. The master assembly **50***b* comprises the base **51**, the outer body **52**, and the top plate **53**, but with a different generally conical center blank **54***b* being used without any outer ring. Here again, the master assembly components **51**, **52** and **56** from the master assemblies **50** and **50***a* are all reused in the master assembly **50***b*.

In the manufacture of a full line of filter products, there are many different configurations of air inlets and air outlets. Some of these configurations can be quite complex, and many have features which cannot be demolded or have fine features that cannot be formed by a conventional gravity molding process. In such instances a separately formed insert member may be used. An example of a complex filter configuration is shown in the filter assembly **10***c* of FIG. **9**. The filter assembly **10***c* comprises a housing formed of a cylindrical side housing member **11** and a pair of end caps **12***c* and **13***c*, forming a filter chamber **14***c* therein. The ends of the side housing member **11** are embedded into the end

caps **12***c* and **13***c*. The first end cap **12***c* includes a gas outlet **16***c* which is formed by a separate outlet tube **63** which is embedded in the end cap **12***c*. The outlet tube is separately molded or machined, and may be made of plastic, steel, aluminum or brass. Since it is made in a separate operation, the outlet tube **63** may be provided with fine details that cannot be formed in the conventional gravity molding process which is used to make the end cap. For example, the outlet tube **63** shown in the drawings is provided with a male nipple configurations on its outer end for connection to a suitable exhaust conduit (not shown). The other end cap **13***c* is provided with a gas inlet **23***c* which is located radially offset from the axis of the filter assembly. The gas inlet **23***c* includes a silencer tube **64** which extends into the filter assembly from the end cap **13***c*, and which is molded into the end cap **13***c*. The silencer tube **64** permits the introduction of dirt laden air into the filter assembly and provides sound reduction by forming an enlarged chamber **14***c* which helps dissipate return sound pressure pulses. Within the filter chamber **14***c* is a cylindrical filter element **32***c* which includes a generally cylindrical media pack **33***c* and a support member **34***c*. The media pack **33***c* is embedded at both ends into the end caps **12***c* and **13***c*, so that it is sealed to the end caps.

The filter assembly end cap **12***c* is molded from the semi-rigid hardenable material similarly to the end caps previously described, but using the flexible mold **39***c*, which is shown in FIG. **10**. The end cap mold **39***c* has side portions **40***c* which fit around and support the cylindrical side housing member **11**, and has a bottom portion **41***c* which forms the outer end profile of the end cap **12***c*. The separately molded outlet tube **63** fits within a corresponding cylindrical opening extending axially in the mold **39***c*. To form the end cap **12***c*, the mold **39***c* is set up horizontally with the mold support **43** as shown in FIG. **10**, and the outlet tube **63** is inserted into the central cylindrical opening in the mold **39***c*. The cylindrical housing member **11** is placed in the mold **39***c*, with the outer side rim **40***c* supporting and positioning the housing member **11**, The end of the housing member **11** preferably rests on a plurality of support tabs **44***c* which extend above the top inner surface of the mold, so that the housing member does not extend entirely through the end cap. The filter element **32***c* is placed in the mold **39***c* with the media pack **33***c* resting on the upper surface of the bottom portion **41***c* and centered in place. A media spacer **45**, such as that

described in US-5 891 337-A may be placed in the mold **39***c* before the media pack **33***c* is placed to prevent the end of the media pack from being exposed to the exterior surface of the end cap **12***c*. The mold **39***c* is then filled to a predetermined level with the semi-rigid hardenable material. The material is allowed to set, after which the end cap **12***c* is removed from the mold **39***c*. The depressions **46***c* formed by the support tabs **44***c* may be filled with an appropriate sealing material such as silicone or caulk. The other end cap **13***c* is then made in essentially the same way, with a different mold configuration to accommodate the silencer tube **64**.

The end cap mold **39***c* is made from a master assembly **50***c* shown in FIG. **11**. The master assembly **50***c* comprises the base **51**, the outer body **52**, and the top plate **53** used with the master assembly **50**, but with a different center blank **54***c* being used with the outer ring **56**. In order to form the central cylindrical opening in the end cap mold **39***c* for the outlet tube **63**, an upper center blank **55***c* is provided on top of the center blank **54***c*. A centering pin **67** is used to maintain the center blanks **54***c* and **55***c* in proper coaxially relationship. While a different center blank is used in the master assembly **50***c*, the master assembly components **51**, **52**, **53** and **56** from the master assembly **50** are all reused in the master assembly **50***c*.

It can thus be seen that the modular master assemblies permit reuse of specially tooled components in a wide array of different shaped masters. By changing components of the master assembly, different end cap molds can be made, and even retainer cap molds can be made. Similarly, the dimensions of the end cap can be easily modified by changing the appropriate component of the master assembly. For example, in the master assembly **50** of FIG. **3**, a larger diameter end cap mold can be made by simply replacing the outer ring **56** with another outer ring having a larger diameter. With each different master assembly, the cost of making and maintaining the master assembly is limited to the cost of each different components. Since many of the components can be reused in different master assemblies, the overall cost of making and maintaining each master assembly is reduced.

The advantages of the present invention can thus be seen in that the end caps can be made in various diameters and in various thickness and in various configurations, and entire new masters need not be made to accommodate all of these changes in dimensions and

configurations. An individual component of the master assembly can be substituted in order to achieve a larger diameter end cap or an end cap having a different outlet or inlet configuration.

While the invention has been shown with respect to a vacuum filter having essentially identical end caps providing axial gas inlets and outlets, it should be understood that the concepts of the present invention can be applied to all types of filters. Filters having configurations such as those shown in US-5 509 948-A can have end caps made according to the method of the present invention. Furthermore, because the molds are made of a flexible material, the designs of the end caps can include undercuts which would previously made conventional molding impossible, unless segmented molds were used.

Other variations and modifications of the specific embodiments herein shown and described will be apparent to those skilled in the art, all within the intended spirit and scope of the invention. While the invention has been shown and described with respect to particular embodiments thereof, these are for the purpose of illustration rather than limitation. Accordingly, the patent is not to be limited in scope and effect to the specific embodiments herein shown and described nor in any other way that is is inconsistent with the extent to which the progress in the art has been advanced by the invention.

# CLAIMS

What is claimed is:

**1.** A method of making a filter assembly, said method comprising a step of:

(a) molding an end cap of said filter assembly in a flexible mold.

**2.** A method according to claim **1**, wherein:

(a) said step of molding comprises molding the end cap in a silicone rubber mold..

**3.** A method according to any one of claim **1** and **2**, wherein:

(a) said step of molding comprises molding the end cap in an end cap mold wherein the mold includes at least one undercut portion.

**4.** A method according to any one of claims **1-3**, wherein:

(a) said step of molding comprises molding said end cap from a hardenable material.

**5.** A method according to any one of claims **1-4**, wherein:

(a) said step of molding an end cap comprises molding an end cap comprising semi-rigid material.

**6.** A method according to any one of claims **1-5**, wherein:

(a) said step of molding an end cap comprises molding an end cap comprising urethane.

**7.** A method according to any one of claims **1-6**, wherein:

(a) said step of molding an end cap comprises molding an end cap comprising foamed urethane.

**8.** A method according to any one of claims **1-7**, wherein:

(a) said step of molding an end cap comprises molding an end cap having an end of a media pack embedded therein.

**9.** A method according to claim **8**, wherein:

(a) said step of molding comprises molding an end cap having an end of a media pack including pleated media, embedded therein.

**10.** A method according to any one of claims **8** and **9**, wherein:

(a) said step of molding comprises molding an end cap having an end of a media pack, including a support member, embedded therein.

**11.** A method according to any one of claims **8-10**, wherein:

(a) said step of molding comprises molding an end cap having embedded therein an end of media including a support member along an interior surface of the media.

**12.** A method according to claim **11**, wherein:

(a) said step of molding comprises molding an end cap having embedded therein a media pack wherein the support member comprises a metal tube.

**13.** A method according to claim **8-12**, wherein:

(a) said step of molding comprises molding an end cap having an end of a cylindrically shaped media pack embedded therein.

**14.** A method according to claim **8-12**, wherein:

(a) said step of molding comprises molding an end cap having an end of a frustoconically shaped media pack embedded therein.

**15.** A filter assembly comprising:

(a) an end cap having an end of a media pack embedded therein, the end cap resulting from a method according to any one of claims **1-7**.

**16.** A method of preparing a flexible end cap mold, comprising the steps of:

(a) assembling an end cap master from a selection of modular components, the components representing different configurations for a portion of the end cap mold; and

(b) molding a flexible end cap from material positioned in the end cap master.

**17.** A method according to claim **16**, wherein:

(a) said step of molding comprises molding a silicone rubber mold.

**18.** A method according to any one of claims **16** and **17**, wherein:

(a) said step of molding comprises molding a flexible end cap mold including at least one undercut portion.

**19.** An end cap mold, comprising:

(a) a flexible mold having at least one undercut portion.

**20.** An end cap mold according to claim **19**, wherein

(a) said mold comprises silicone rubber material.

**21.** An end cap mold according to claim **19**, prepared according to the method of any one of claims **16-18**.

**22.** A method of molding a filter assembly, said method comprising the steps of:

(a) molding an end cap mold from an end cap master; and

(b) molding a filter assembly end cap, with an end of a media pack embedded therein, from the end cap mold.

**23.** A method according to claim **22**, wherein:

(a) said step of molding an end cap mold comprises a method according to any one of claims **16-18**.

**24.** A method according to claim **23**, wherein:

(a) said step of molding a filter assembly end cap comprises a method according to any one of claims **1-7**.

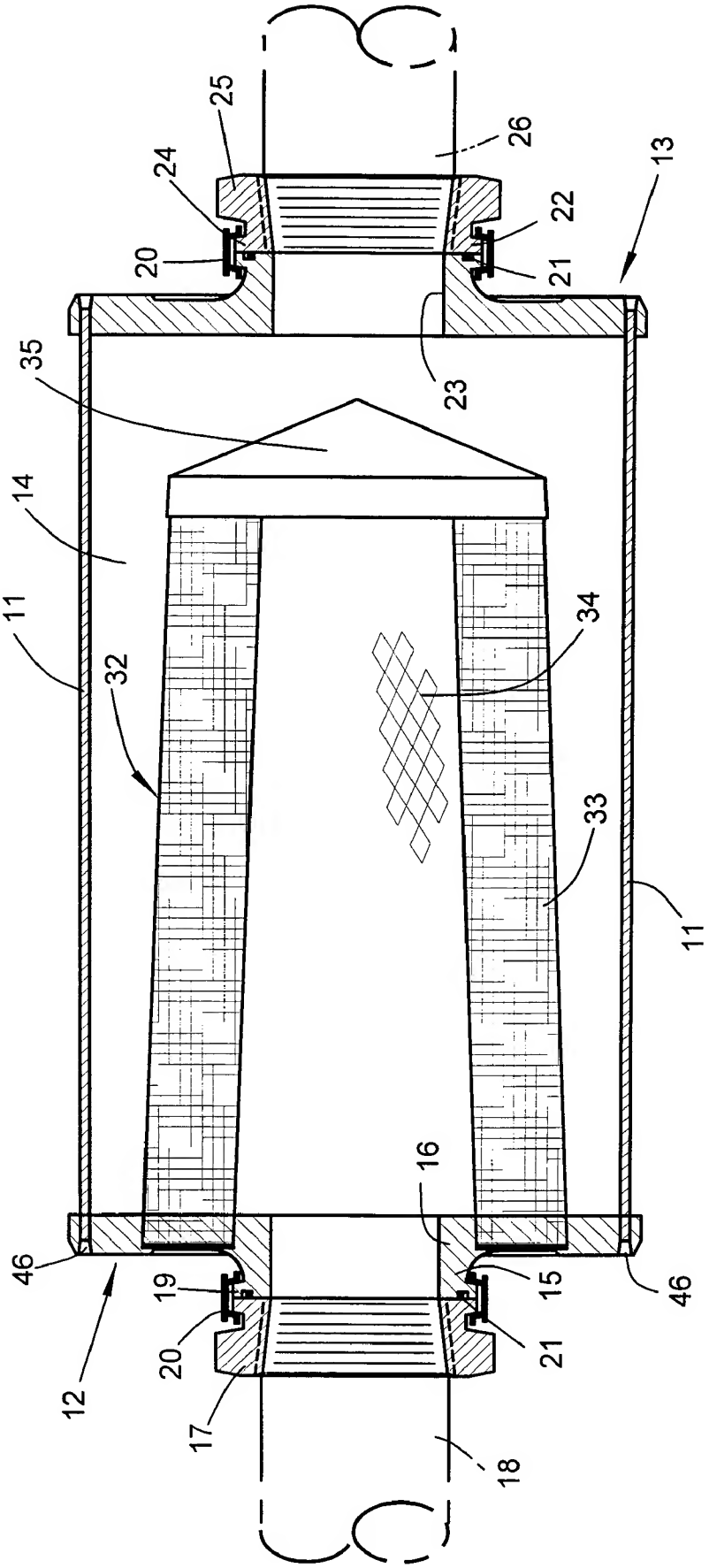
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FIG. 1

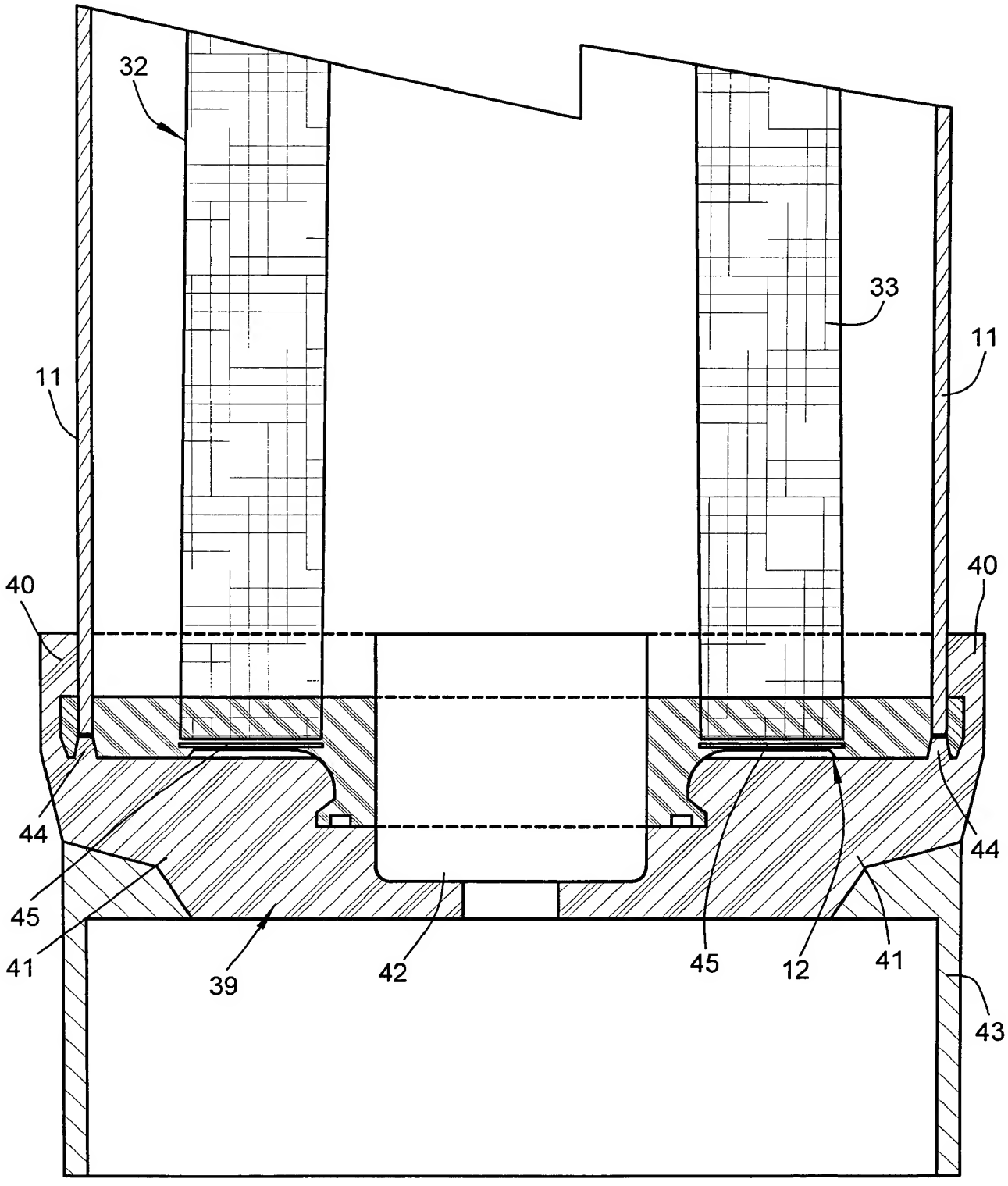


FIG. 2

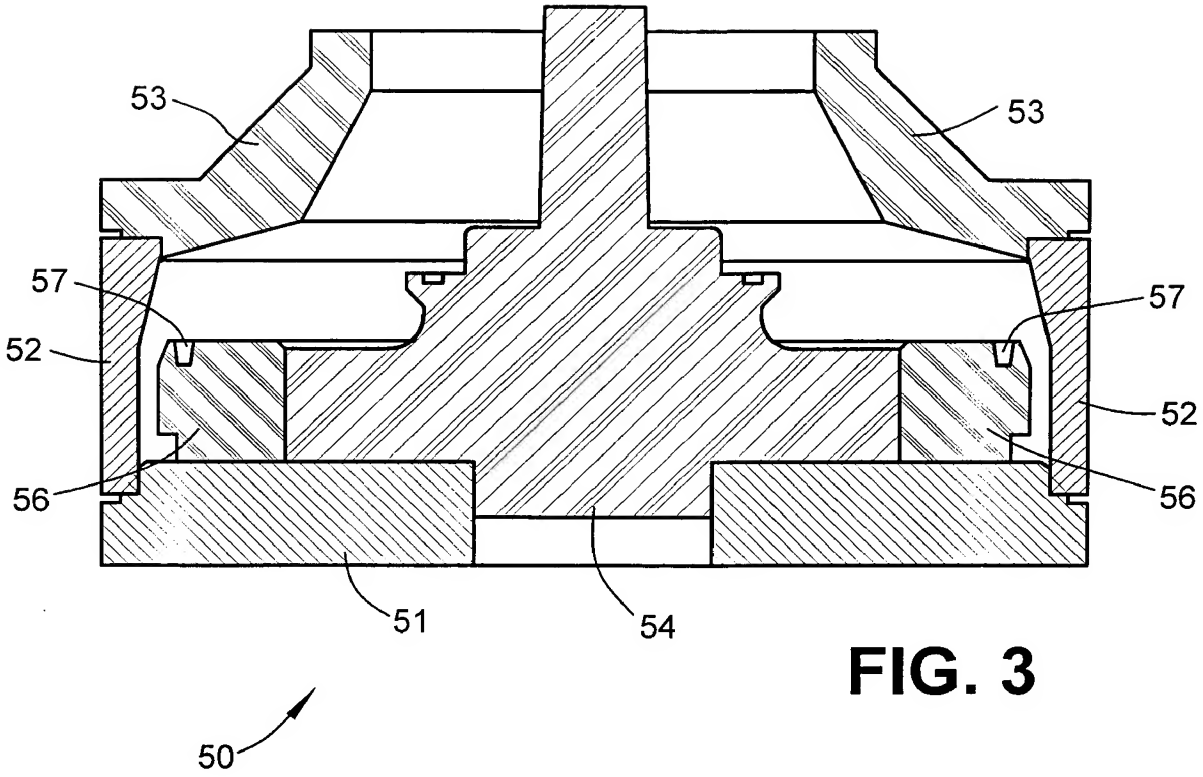


FIG. 3

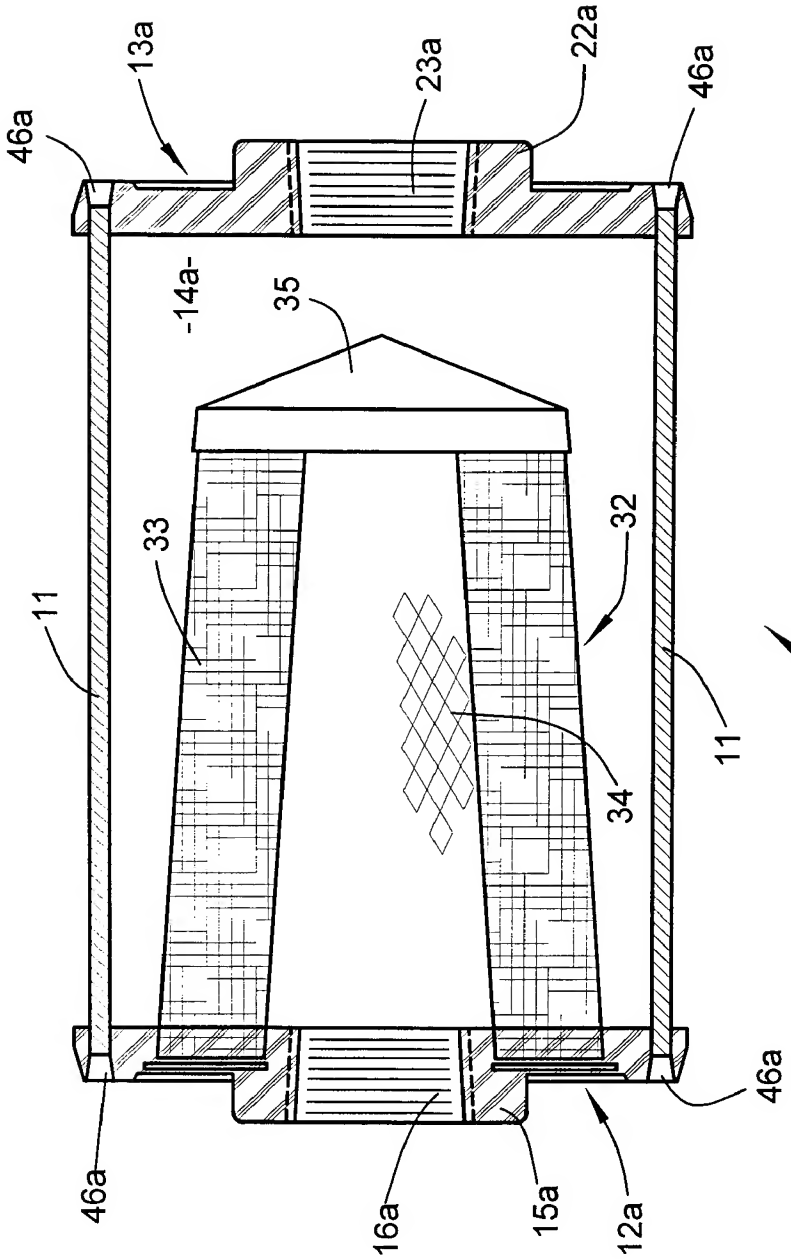


FIG. 4

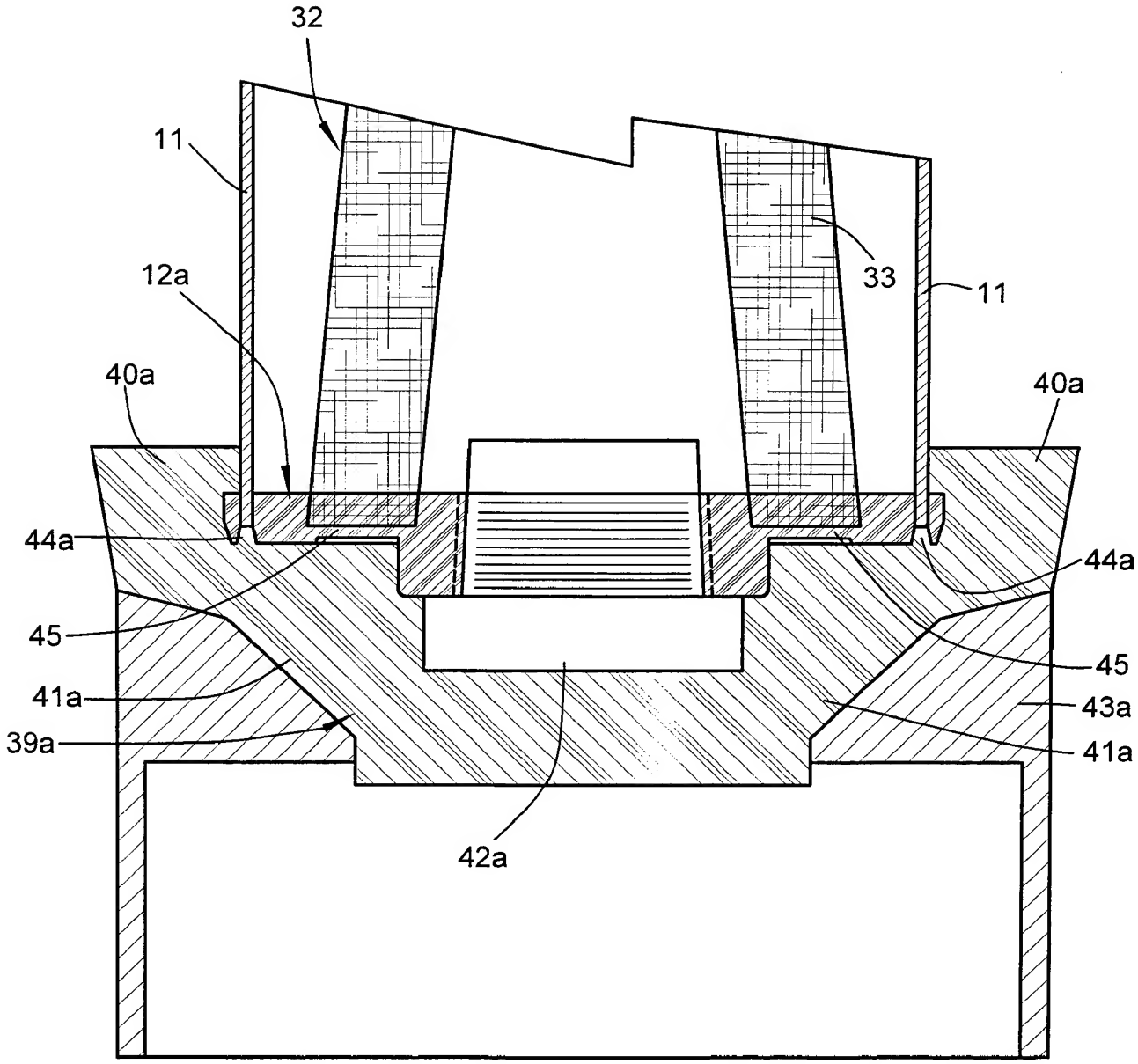


FIG. 5

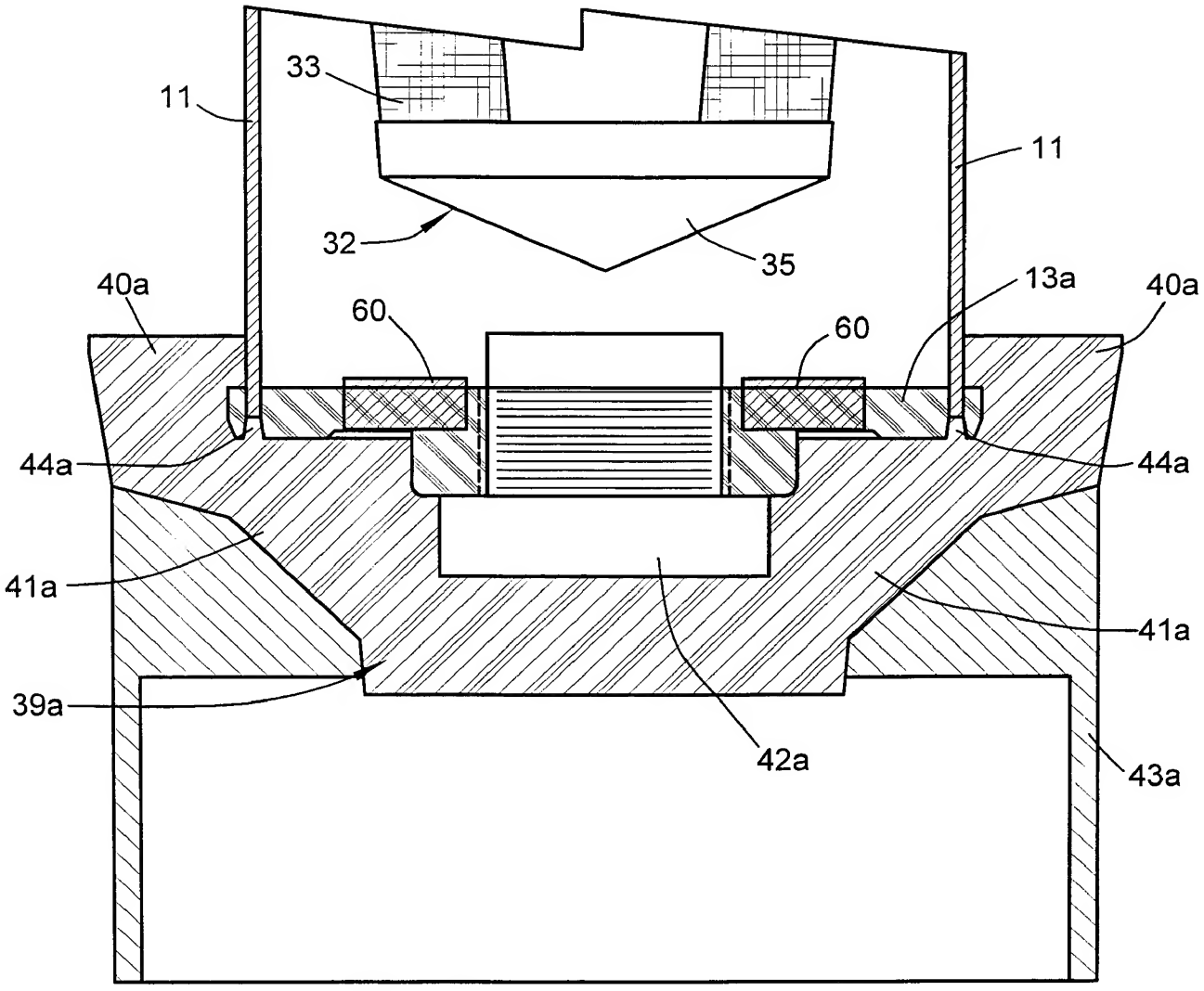


FIG. 6

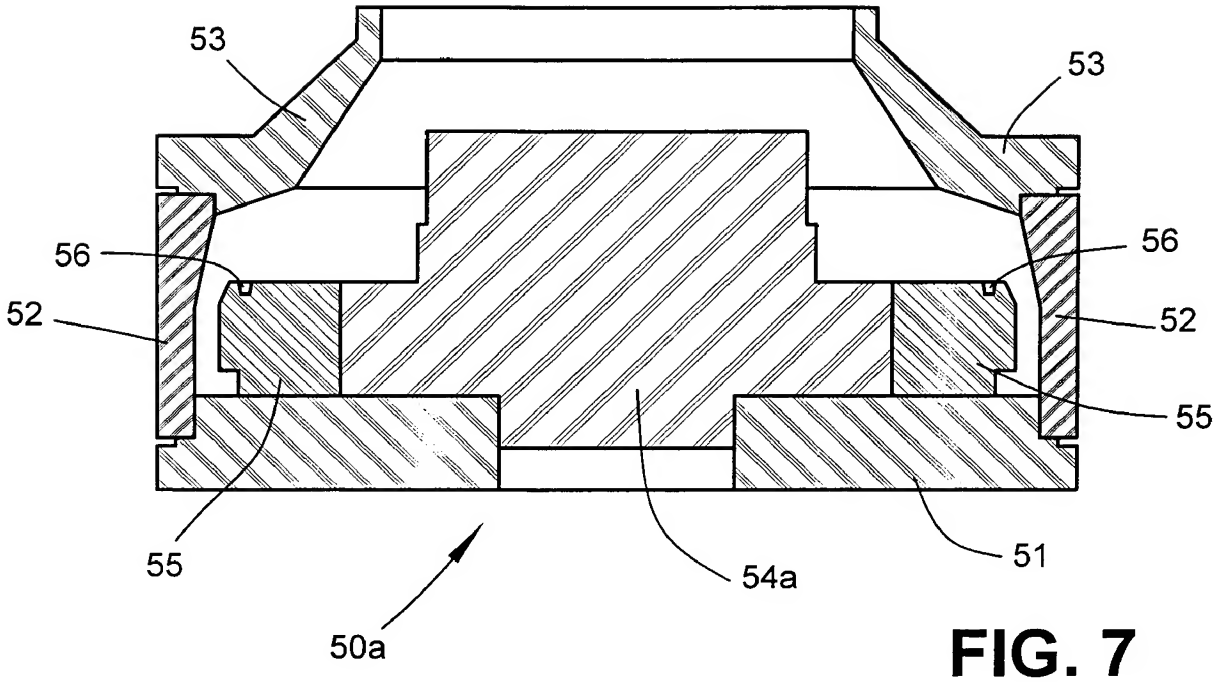


FIG. 7

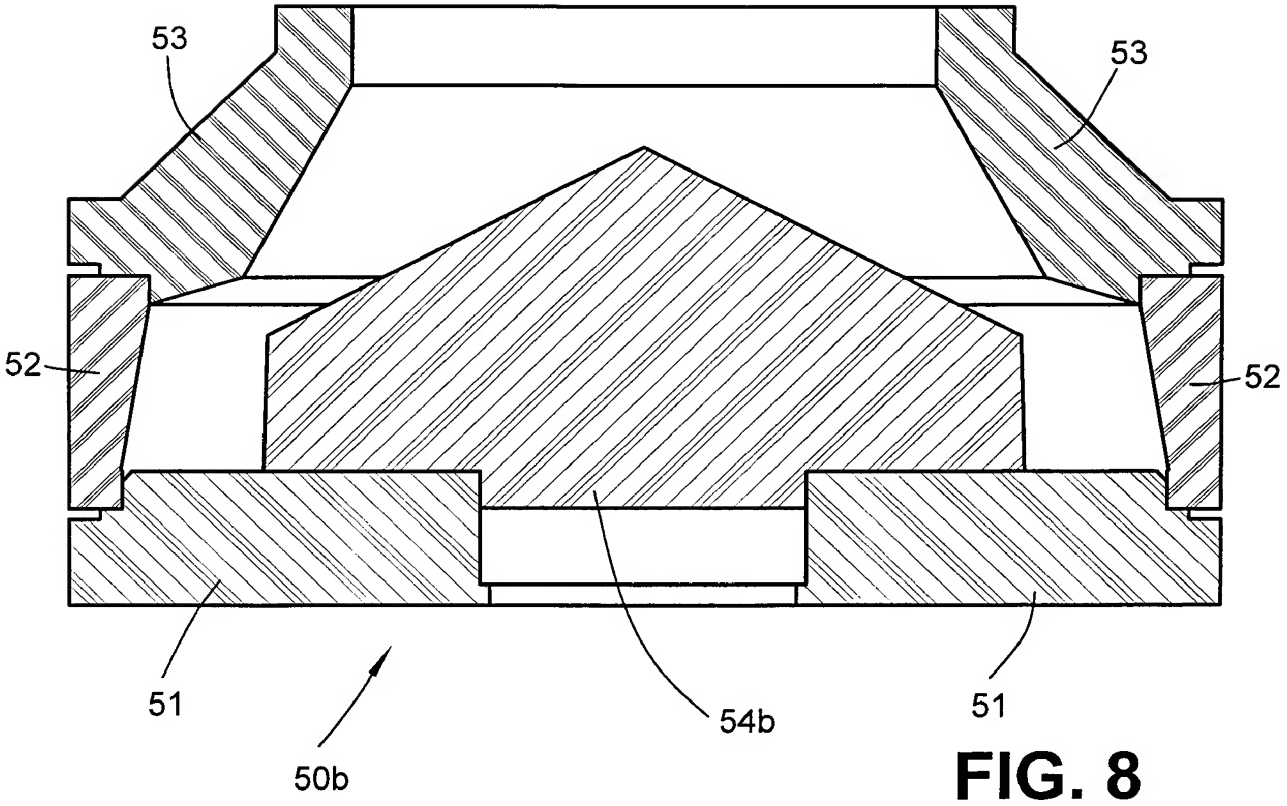


FIG. 8

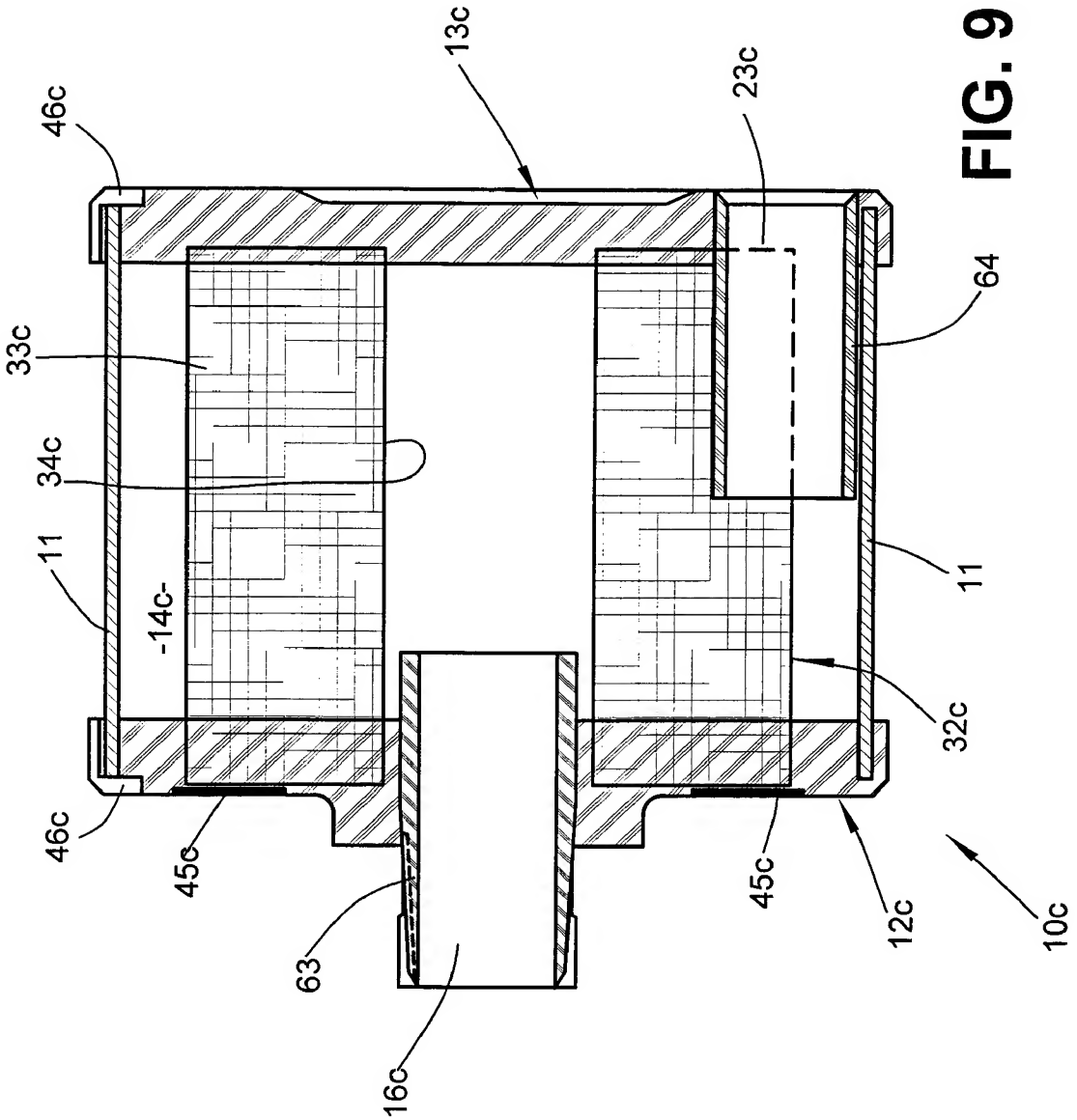


FIG. 9

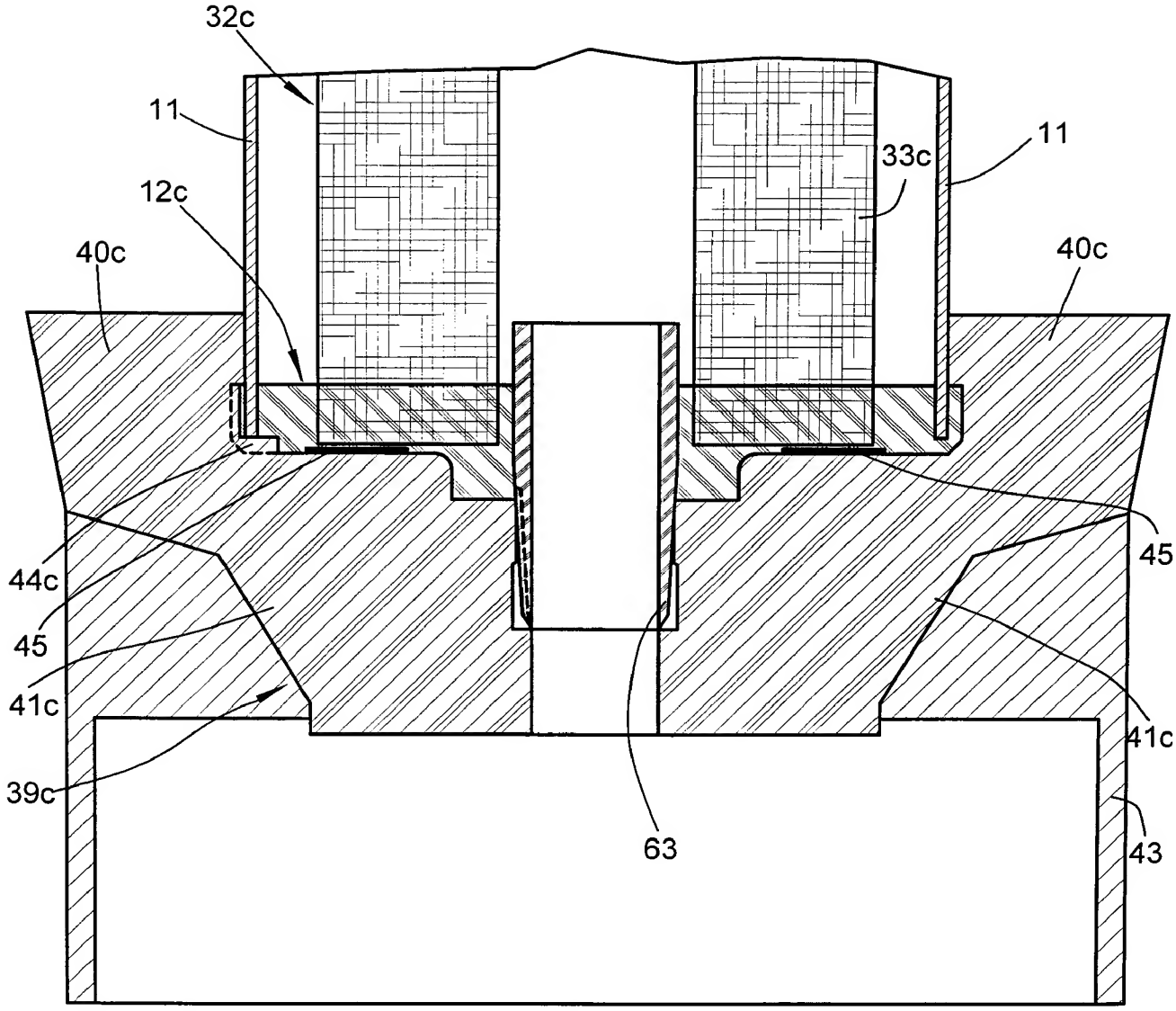


FIG. 10

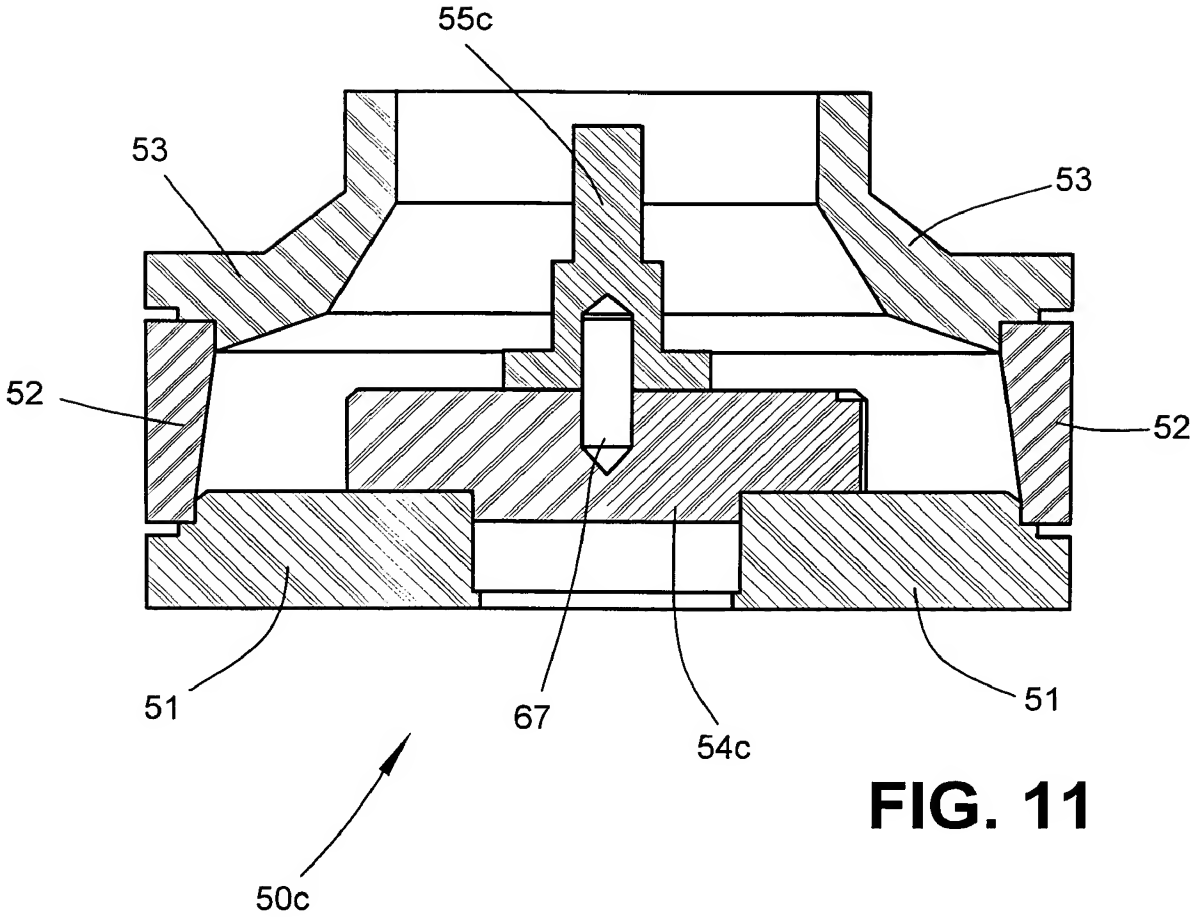


FIG. 11